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SHAREBOX
SECURE SHARING

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Table of Contents

Abbreviations

BAU	Business-as-usual
ICT	Information & Communication Technology
NISP®	National Industrial Symbiosis Programme, a registered trademark of International Synergies Ltd.
SME	Small and Medium Enterprises

Publishable Executive Summary

Industrial symbiosis is a recognised tool for resource efficiency, circular economy, and eco-innovation. The two main approaches to industrial symbiosis implementation can be disaggregated as: facilitated (or practitioner-enabled) with ICT support ('facilitated/ICT'), or 'ICT alone'.

The 'facilitated/ICT' model refers to the use of facilitators who support the implementation of industrial symbiosis between two or more companies through a number of phases/gateways; company engagement and data collection with the facilitated model is very high. The 'ICT alone' model has also been implemented in countries around the world, usually taking the form of a passive online waste exchange, however, company engagement with non-facilitated industrial symbiosis and data collection 'ICT alone' has historically been low. Regardless, given the benefits of industrial symbiosis, there have been attempts to foster its uptake on a large scale predominantly through 'ICT alone'.

SHAREBOX will develop the next generation online resource management database that supports industrial symbiosis implementation principally through 'ICT alone', by (and as far as possible) incorporating practitioner experience and knowledge which has successfully overcome non-technical barriers to industrial symbiosis in a way that the current passive 'ICT alone' systems clearly do not.

To identify the non-technical barriers experienced by companies, and how facilitation overcomes them, data were gathered using two distinct methods: first, to understand the company perception of barriers and benefits of industrial symbiosis, an online survey was created and distributed to businesses in four countries involved in the eight SPIRE industry sectors. Second, the role of facilitation was investigated via semi-structured interviews with facilitators implementing industrial symbiosis in eight countries.

Of the non-technical barriers to industrial symbiosis explored through survey and interviews, c**ommercial viability** is not an area for substantial practitioner intervention: companies do not need (much) help with building the commercial case. Both companies and practitioners identify **regulation and policy** as potential barriers, usually addressed through practitioner support. The lack of **information availability** is clearly identified as a barrier by companies, and addressing this is a large part of the practitioners' role. Finally, **organisational and governance** issues are acknowledged as a barrier by both practitioners and companies, also often overcome through facilitation.

1. Introduction

Industrial symbiosis is a recognised tool for resource efficiency, circular economy, and eco-innovation. Given the benefits of industrial symbiosis, there have been many attempts to foster its uptake on a large scale predominantly through ICT (information and communication technology), dating back to the original United States Environmental Protection Agency's attempts in the 1990s[1]. Today the two main approaches to industrial symbiosis implementation can be disaggregated as: facilitated with ICT support ('facilitated/ICT'), or 'ICT alone'.

The 'facilitated/ICT' model refers to the use of facilitators (also known as practitioners) who support the implementation of industrial symbiosis between two or more companies through a number of phases, from opportunity identification to the establishment of a synergy. The 'facilitated/ICT' model has been implemented in at least 30 countries around the world, largely with the support of International Synergies. Engagement with the facilitated model is high: International Synergies' NISP® UK has engaged over 15,000 companies in its 8 years operating nationally, and another estimated 5000 companies through partners globally. This approach captures various underutilised resources beyond materials, including: water, energy, capacity, logistics, and expertise. International Synergies' database and management programme SYNERGie® is used in conjunction with the NISP® model to store data gathered, and to manually identify viable synergies. Practitioners then use this information to facilitate synergies between companies, tracking and reporting results via SYNERGie®.

The 'ICT alone' model has also been implemented in countries around the world, usually taking the form of a passive online waste exchange. Waste exchanges tend to capture material resources available from users, without providing support in identifying potential partners for projects or novel applications for those resources. Engagement with non-facilitated industrial symbiosis 'ICT alone' has historically been low: for example, an online waste exchange in South Africa listed only 100 resources after 14 years, whereas one year of the NISP programme running in the same region captured detailed information on 465 resources. The facilitated programme in France has engaged over 350 sites and captured more than 4500 resources in under a year. 'Facilitated/ICT' is not as easily scalable as 'ICT alone', due to the investment required in facilitators versus the running costs of maintaining an online platform.

The common barriers to industrial symbiosis are:

- Regulatory and policy barriers: inconsistent or unclear regulations leading to risk-avoidance, or regulations that prohibit the reuse or storing of materials deemed waste;
- Commercial barriers: whereby a synergy does not meet company thresholds for advancing the opportunity;
- Information barriers: lack of knowledge within a company of what kind of synergies are possible for a particular sector, or where to look for opportunities outside its industry sector;
- Organisational and governance barriers: lack of will to pursue a project that is not business-as-usual (BAU), lack of time within companies to search for, identify and advance opportunities from a resource database.

[1] Brown et al (1997) *The Matchmaker! System: Creating Virtual Eco-Industrial Parks,* Yale, Yale School of Forestry and Environmental Studies, 1997

SHAREBOX aims to develop the next generation online resource management database that supports industrial symbiosis implementation principally through 'ICT alone' by overcoming the barriers to industrial symbiosis that the current passive 'ICT alone' systems do not address – i.e., a scalable 'ICT alone' system that delivers the engagement and impacts of 'facilitated/ICT' model without the associated personnel costs. It is thus crucial to understand the non-technical barriers that facilitation overcomes, and design the SHAREBOX resource management database accordingly.

In this report, the hypothetical barriers to industrial symbiosis are tested with industrial companies and industrial symbiosis practitioners through surveys and interviews. The following questions regarding non-technical opportunities and barriers to industrial symbiosis are addressed:

1. What benefits of industrial symbiosis do companies value most? What motivates them to implement industrial symbiosis?
2. What are the non-technical barriers that companies face when implementing industrial symbiosis?
3. How does facilitation address and/or overcome said non-technical barriers?

Once the benefits and barriers are understood, the means to address them may be programmed into the SHAREBOX resource management database to support the 'ICT alone' model of industrial symbiosis.

2. Non-technical barriers to Industrial Symbiosis

Lombardi & Laybourn's definition of industrial symbiosis highlights the complexity of achieving industrial symbiosis by identifying the numerous aspects that combine to produce industrial symbiosis: 'industrial symbiosis engages *diverse organisations* in a *network* to foster *eco-innovation* and *long-term* culture change. *Creating and sharing knowledge* through the network yields mutually *profitable transactions* for *novel sourcing of required inputs*, *value-added destinations for non-product outputs*, and *improved business and technical processes*.'[2] Each of the terms in italics is fundamental to achieving industrial symbiosis. The article goes on to illustrate that once barriers are overcome, industrial symbiosis becomes BAU in the sense that companies are well versed in assessing risk, intellectual property and evaluating projects for commercial viability and these BAU processes take over once the opportunity is identified.

From practical experience in over 30 countries on 5 continents, International Synergies has identified the following 4 top-level non-technical barriers to industrial symbiosis implementation, common across all economies and cultures.

2.1. Regulatory and policy barriers

The classification of a material as 'waste' has fundamentally important commercial consequences, including transportation and disposal requirements. To promote waste re-use, there is a need for a clear definition of waste, and perhaps more importantly, clarity on when something ceases to be waste. The legal definition of waste can be vague and dependent on factors other than the composition or possible after-use of the material. Where there is confusion over the definition of waste, either within a country's legislation or internationally, it hinders the successful implementation of the waste hierarchy that aims at diverting waste away from landfill by promoting sustainable waste recycling and re-use.

Regulation can also present a barrier to industrial symbiosis (actual and perceived), through inconsistent and inflexible regulation and enforcement. Where the interpretation of the regulatory

[2] Lombardi, DR & PT Laybourn. 2012. Redefining Industrial Symbiosis: Crossing Academic-Practitioner Boundaries. Journal of Industrial Ecology 16(1): 28-37

regime is unclear, companies are often hesitant to request clarification (for fear of attracting regulator attention and possible associated consequences) and in turn the regulators may be unwilling to risk a liberal interpretation that would allow synergies to advance even if there was a 'total' or aggregate environmental benefit.

European policies related to industrial symbiosis include:

- **2008 The Raw Materials Initiative** COM 2008 699 final sets out a strategy for tackling the issue of access to raw materials in the EU. This strategy has three pillars which aim to ensure:
  - Fair and sustainable supply of raw materials from global markets;
  - Sustainable supply of raw materials within the EU;
  - Resource efficiency and supply of "secondary raw materials" through recycling.
- **2011 The Resource Efficiency Roadmap** COM (2011) 571 final outlines how we can transform Europe's economy into a sustainable one by 2050. It proposes ways to increase resource productivity and decouple economic growth from resource use and its environmental impact. It illustrates how policies interrelate and build on each other.
- **2012 A Stronger European Industry for Growth and Economic Recovery - Industrial Policy Communication Update** COM(2012) 582 final **Quote:** Tomorrow's factories will use highly energy- and material-efficient processes, employ renewable and recycled materials, and increasingly adopt sustainable business models such as industrial symbiosis to recover materials and dissipated heat and energy.
- **2013 Review of the 7th Environmental Action Programme**. The Action Programme will be guiding European environment policy until 2020. It identifies three key objectives:
  - to protect, conserve and enhance the Union's **natural capital**
  - to turn the Union into a **resource-efficient**, green, and competitive low-carbon **economy**
  - to **safeguard** the Union's citizens from **environment-related pressures** and risks to health and wellbeing
- **2014 Communication on Green Action Plan for SMEs** COM (2014) 440 final. **Quote:** Address systemic barriers to cross-sectoral and cross-national value chain collaboration and business creation and cooperation, by facilitating the creation of service business models and the re-use of materials, products and waste: ƒ Analysis of the systemic barriers impeding the deployment of circular business models by SMEs, the efficient use of materials from waste streams and industrial symbiosis processes. This is crucial for developing the best possible actions at EU level to address these shortcomings and to promote the role of SMEs in the circular economy.
- **2014 DG GROW, Green Employment Initiative: Tapping into the job creation potential of the green economy** COM(2014) 446 final This Communication aims at defining strategic framework conditions to allow labour market and skills policies to play an active role in supporting employment and job creation in the green economy.
- **2014** EUROPEAN RESOURCE EFFICIENCY PLATFORM: Manifesto & Policy Recommendations **Quote:** "The EU and Member States should foster industrial symbiosis by promoting a pan-European network of industrial symbiosis initiatives, under which facilitators could be connected to allow match-making, including across borders and beyond the EU. The potential for creating new, or scaling up existing, networks should be exploited and a platform

for knowledge exchange established. This would help companies to source inputs and to get value from their residues."

- **2015 EU action plan for the Circular economy** COM(2015) 614 final Communication-recommendation on industrial symbiosis: The Commission proposed (in the revised legislative proposals on waste) to clarify rules on by-products to facilitate and help create a level-playing field across the EU.

EU policies and recommendations incorporating industrial symbiosis help create the context for industrial symbiosis in Member states; however, implementation of EU Directives varies, often substantially, across Member States, introducing a degree of variability that can hinder industrial symbiosis in practice. At the Member State level, there are policies that support industrial symbiosis (e.g. high levels of landfill tax) but few that explicitly incorporate it at the national or regional level. Furthermore, at the Member State level and more locally, inconsistent interpretation and implementation between regions/States present challenges to materials moving between regions/States.

2.2. Commercial barriers

Industrial symbiosis relies on identifying business opportunities deriving from improved resource efficiency, and requires the appropriate market conditions to create and incentivise opportunities. In some cases, a technically feasible industrial symbiosis opportunity does not provide the commercial benefit required from the partners to meet requirements for cost-benefit or return on investment, and it does not proceed, despite environmental benefits.

Policy stakeholders and business leaders alike are calling for policies that "get the prices right" to incentivise resource efficient behaviour – this includes carbon, but also water, landfill, and other raw materials. Conditions vary widely, even across Europe where the landfill tax ranges from very low to relatively high, to a ban on landfilling altogether (see Figure 1, below).

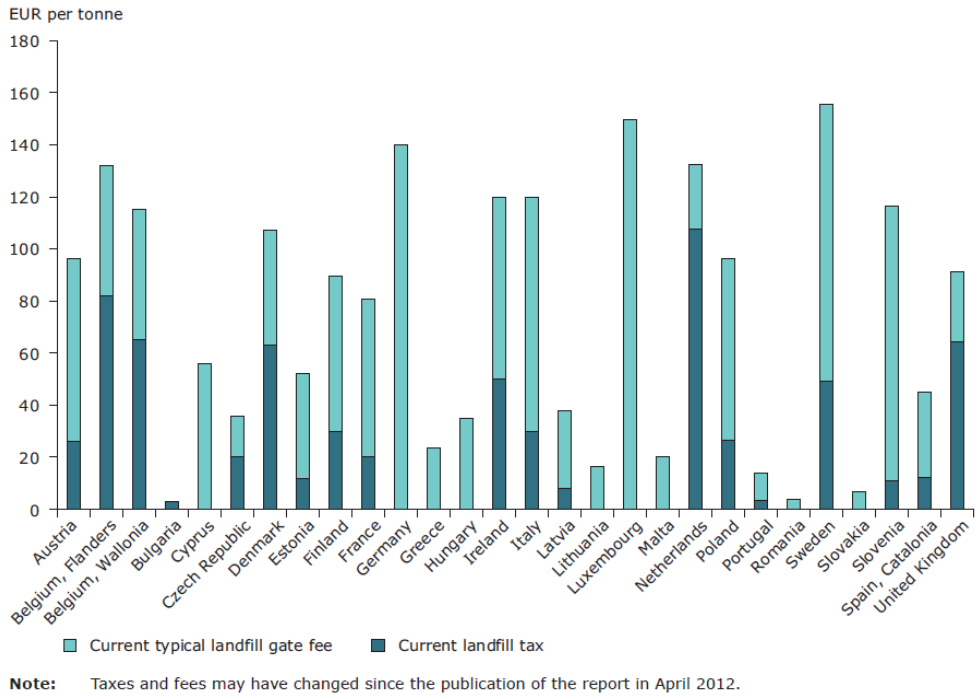
Interventions that distort market signals include fossil fuel subsidies that lessen the relative benefit of pursuing renewable fuels, for example. Additional interventions distorting the market signals include government investment in certain installed waste treatment capacity (for example waste-to-energy and anaerobic digestion), as the associated contracts (long-term, exclusive, or both) and demand on feedstock make it difficult to redirect resources back into productive use. Vested interests in the wastes management sector may hinder alternative arrangements that upcycle waste to resource through exclusive contracts, while seeking opportunities to monetise the wastes under their control. A further challenge is the sometimes small quantities of resources available from companies (largely SMEs).

Branson[3] undertook a comprehensive examination of factors influencing the implementation and uptake of industrial symbiosis in NSW, Australia, whilst exploring three hypotheses around companies' propensity to undertake industrial symbiosis of their own accord and the conditions under which industrial symbiosis can be replicated on a larger scale. The study revealed that financial benefit is the 'paramount consideration, commensurate with acting legally' (Branson, 2011).

[3] Branson, R. (2011) *Bilateral Industrial Symbiosis, an Assessment of its Potential in New South Wales to Deal with Manufacturing Waste,* University of Sydney, School of Geosciences, 2011

A further influencing factor on the commercial viability of a synergy, especially those that require innovation or can only be completed over an extended time period is the availability of finance. Although this is particularly true for micros/SMEs, even larger companies will hesitate on pursuing some synergies without some initial subsidy or grant intervention at the start. In some European economies, including the UK, the low level of bank lending to SMEs since the 2008 financial crisis has been identified as a barrier to growth. Facilitators through their knowledge and/or network of contacts have been able to assist companies by signposting to available grants whether at a local, regional or national level.

Figure 1 Typical charge (gate fee and landfill tax) for legal landfilling of non-hazardous municipal waste in EU member states and regions



Source: Bio Intelligence Service 2012, cited in EEA 2013, Managing Municipal Solid Waste, 2013.

2.3. Informational barriers

In their exploration of the shortfalls of ICT when facilitating industrial symbiosis, Grant and colleagues[4] identify information exchange as crucial to all stages of industrial symbiosis implementation; for example, the processes of opportunity identification and assessment, whereby businesses may identify opportunities through new process discovery, input-output matching or relationship mimicking, all of which depend on having access to the right information. Opportunities may be assessed through methods such as cost benefit analysis, process life cycle analysis and/or economic input-output life cycle analysis for which access to information is also crucial.

Real time, accurate data are critical to operationalise industrial symbiosis effectively. There is a perception that making information about resources public (i.e. on a web-based waste exchange) is sufficient to advance resource reuse. For well-established recyclate markets (paper, card, glass, some

[4] Grant et al (2010) "Information and Communication Technology for Industrial Symbiosis." *Journal of Industrial Ecology* 14(5): 740-753

plastics) that may be the case – but the strength of industrial symbiosis is thinking innovatively about the resources: egg shells aren't just egg shells (and waste to a baker) they are also a source of minerals and collagen (and as such, a potential alternative raw material to other industries). It is this potential innovation moving a resource up the value chain that is generally lacking from current web-based and non-facilitated systems. Similarly, web-based exchanges do little to address quality of information (quantities, current destination, contamination, distribution and timing issues), which are vital to optimise re-use. In addition, passive waste exchanges do little or nothing to advance industrial symbiosis in non-material (solid) resources including energy, water, logistics, asset utilisation, expertise etc.

2.4. Organisational/governance barriers

The absence of certain conditions internal to a company may become barriers to industrial symbiosis, namely: corporate culture, motivation and structure[3]. According to Branson, an organisation has to be sufficiently flexible to allow a project champion to pursue unconventional, perhaps counterintuitive ideas and be willing to support those efforts. There must be corporate motivation to pursue an opportunity (generally financial) and a conducive corporate structure is required, namely one that is not underpinned by a silo approach, whereby a lack of communication and cooperation between departments can inhibit industrial symbiosis (Branson, 2011). In International Synergies' experience these organisational barriers apply equally to small, medium, and large companies – although small companies often suffer more from lack of resources.

Much analysis and literature around this subject starts from the premise that companies are rational actors. This is not necessarily the case. Certainly International Synergies has experienced being able to put forward excellent business cases for synergies with potentially high rates of return and have then found for whatever reason (not wanting to change, perceived too much effort, timing not quite right, politically difficult to gain internal consensus etc.) that companies are unwilling to progress.

Fundamentally, SMEs and micros typically do not have the time or priority to allocate to these types of searches. Programme managers on the SME agenda find that SMEs are lacking institutional support to take advantage of the economic opportunities in resource efficiency, and encounter significant barriers to entry.

3. Methodology

Data were gathered using two distinct methods: first, to understand the company perception of barriers and benefits of industrial symbiosis, an online survey was created and distributed to businesses in 4 countries involved in the eight SPIRE industry sectors. Second, the role of facilitation was investigated via semi-structured interviews with facilitators implementing industrial symbiosis in eight countries.

3.1. Survey structure and questions

The survey established whether companies were familiar with the concept of industrial symbiosis (by enquiring whether they had practised it) and what they saw as being the main challenges (barriers) and benefits (motivations) associated with industrial symbiosis. Companies were also asked questions related to their use of an 'ICT alone' approach (via online waste exchanges). The questionnaire focuses on materials (versus expertise, innovation, water, energy, logistics etc. – the usual breadth of assets that industrial symbiosis addresses) in order to make a direct comparison to traditional 'ICT alone' waste exchanges.

The structure of the survey is depicted in Figure 2. Questions were tailored based on respondents' response to the previous question, thus the figure below is a representation of the various paths respondents could take through the survey. Respondents were able to select multiple answers from the following list of options for perceived benefits and challenges associated with industrial symbiosis (see Table 1).

Table 1 Online survey: perceived benefits and challenges of industrial symbiosis

Benefits	• Revenue generation • Reduced cost of waste disposal • Improved environmental performance of the company • Improved environmental performance of the community • Reduced cost of inputs • Adherence to regulatory requirements • Improved quality of inputs • Improved links with other businesses • Opportunity to implement a similar process in other areas of the business • Satisfaction of CSR requirements • Other
Challenges	• Contractual barriers • Logistical barriers • Transport barriers • Process barriers • Regulatory barriers • Financial barriers • Coordination barriers • Concerns about confidentiality • Lack of time to implement solutions • Long timeframe for implementation of solutions • Lack of information regarding alternative feedstock/inputs • Gaining approval from relevant authorities

Companies were approached via the SHAREBOX partners (businesses within the partner industrial parks) and SPIRE. SHAREBOX partners received an invitation by email, and followed a link to the online survey. SPIRE members had the additional option of a link on their website. The survey was available for completion over the course of four weeks, February - March 2016.

A total of 65 surveys were completed; respondents represented all 8 SPIRE industry sectors, with the greatest numbers of responses from chemical, ceramics and steel industry sectors (see Figure 3). The majority of companies were familiar with the concept of industrial symbiosis, as 58 of 65 companies had tried to find alternative uses for their waste and a further 5 companies had considered finding recycled alternatives to raw materials used. Those that had not engaged in industrial symbiosis activity were provided with a definition, then asked whether they perceived benefits or challenges, or had interest in an online waste exchange.

Figure 2 Structure of business survey on the uptake of industrial symbiosis

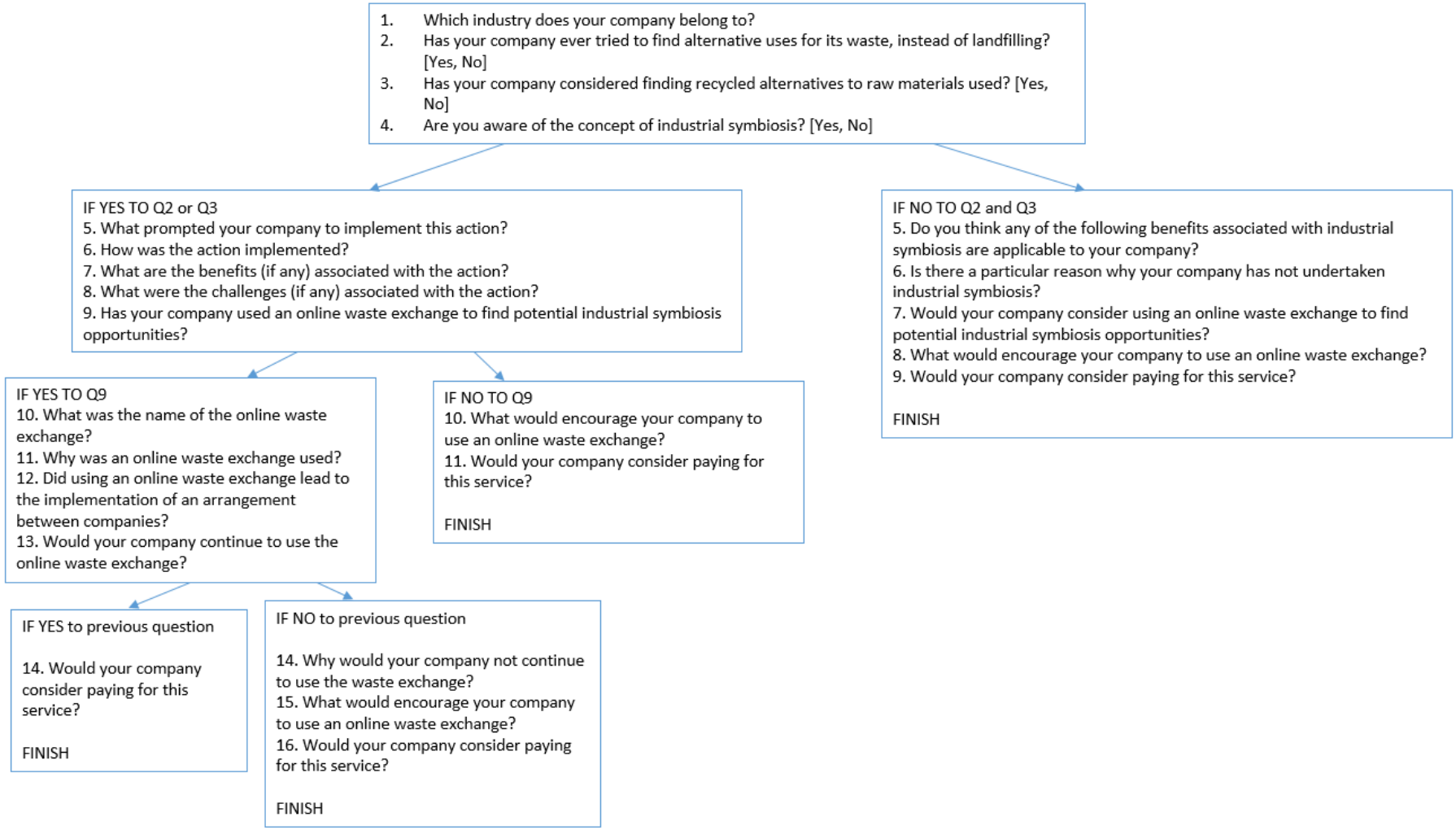
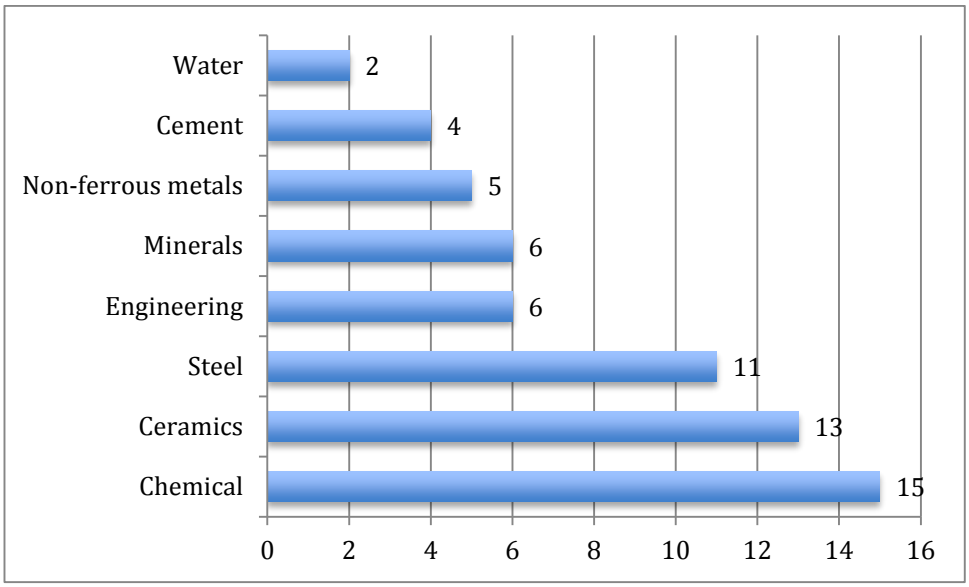


Figure 3 Survey results: respondents' industry representation



The survey was available in English, German, Spanish and Turkish. In total, 65 surveys were completed in the four languages: 30 in Turkish, 19 in English, 12 in Spanish and 4 in German. The results have been collated in each of the languages and have been presented as such in section 4, so that country-specific trends can be identified. The English language survey was available to all participants in all countries. It is possible that people in non-English speaking countries completed the English language survey, which could skew any generalisation of the English language results.

3.2. Practitioner interview structure and questions

Practitioners working within the facilitated/ICT NISP® model were interviewed from Belgium, Finland, Ghana, Hungary, Italy, Northern Ireland, South Africa and England. The following questions were asked with respect to businesses' perceived capability and willingness to engage in industrial symbiosis, their likelihood to use ICT for industrial symbiosis, and the role of facilitation:

- Under what circumstances do businesses have a good idea of available alternatives for raw materials?
- In your opinion, would businesses search for their own alternative resources if they had the mechanism to do so?
- In your opinion, would businesses have enough technical/specialist knowledge to form synergies on their own?
- What do you think the benefits are, if any, of having a third party facilitator?

Practitioner interviews were conducted via Skype and responses were recorded by hand as the interviews progressed. A single practitioner was interviewed per country, except for Hungary and Italy, where two practitioners participated in each of the interviews, and England, where a group of five practitioners were interviewed in person. The practitioners interviewed were generally those responsible for running a NISP® team and programme. The interviews were undertaken over a two-month period from October - December 2015.

4. Analysis and Discussion of Key Findings

4.1. Online survey responses

Benefits

Contrary to expectation and experience, respondents indicated that environmental factors were the most significant perceived benefit associated with industrial symbiosis: 'improved environmental performance of the company' ranked highest across all four languages; and 'improved environmental performance of the community' ranked third overall. Identifying environmental (rather than financial) benefits as primary is not consistent with either the literature or with International Synergies' experience. Various studies indicate a bias for businesses to respond positively about environment where actions do not follow – the classic environmental economics 'willingness to pay' conundrum; a 2002 UNEP study concluded that only a small percentage of companies were actively integrating environmental factors into decision-making. It may be that in the nature of the respondents there was an inbuilt bias to answer what they think they ought to prioritise (environment) over the real case (financial).

Financial concerns ranked highly as expected: 'reduced cost of waste disposal' is the second most common benefit, 'revenue generation' is ranked fourth, while 'reduced cost of inputs' ranked seventh. The emphasis on reduced cost of waste disposal over reduced cost of inputs (46 versus 17 selections) may be indicative of the common perception of industrial symbiosis for waste management, whereas its applicability to inputs/feedstock, let alone energy, water, innovation etc., is less well-known. This is supported by the NISP® global experience, where participating companies generally produce more than twice as many resources (waste) available for use than resources wanted as inputs; the benefit of 'improved quality of inputs' received only 6 selections in this survey.

Table 2 Survey results: benefits of industrial symbiosis

	Turkish	Spanish	German	English	**Total**
Improved environmental performance of the company	20	11	2	13	**46**
Reduced cost of waste disposal	14	10	4	12	**40**
Improved environmental performance of the community	12	5	2	10	**29**
Revenue generation	11	7	2	6	**26**
Adherence to regulatory requirements	15	1		7	**23**
Satisfaction of CSR requirements	9	4		9	**22**
Reduced cost of inputs	6	6		5	**17**
Opportunity to implement a similar process in other areas of the business	3	1	1	4	**9**
Improved links with other businesses	3		1	4	**8**
Improved quality of inputs	4	1		1	**6**
Other	1	1			**2**

Barriers

The most commonly identified challenge to implementing industrial symbiosis is that of 'process barriers', with 24 selections, intended to capture internal production-based hurdles, for example incorrect material specifications or lack of storage space.

Regulation, financial and transport barriers all received similar rankings with respect to their impact on the implementation of industrial symbiosis (20, 20 and 19). These are all aspects that have been successfully influenced through facilitated industrial symbiosis, as they are fundamental to the context of the companies looking to form a synergy. The next set of highest rated barriers include 'lack of information regarding alternative feedstock/inputs', 'lack of time to implement solutions' and 'long timeframe for the implementation of solutions' (16, 14 and 12 respectively). These are also overcome through facilitation by the provision of free assistance to businesses to gather relevant information, making connections and supporting the synergy progression.

The least common challenges cited were coordination barriers, concerns about confidentiality, gaining approval from relevant authorities, contractual barriers and logistical barriers. The fact that coordination, confidentiality and contractual barriers are not highly ranked supports the position that a contract for goods or services involving industrial symbiosis is generally perceived as BAU, not something exceptional[5]. Although regulatory barriers were ranked highly, 'gaining approval from relevant authorities' were not; similarly, transport barriers were ranked highly, but not 'logistical barriers'. The survey did not allow for free text entries that would have enabled a further explanation of these responses (with benefit of hindsight, an error).

Table 3 Survey results: challenges associated with implementing industrial symbiosis

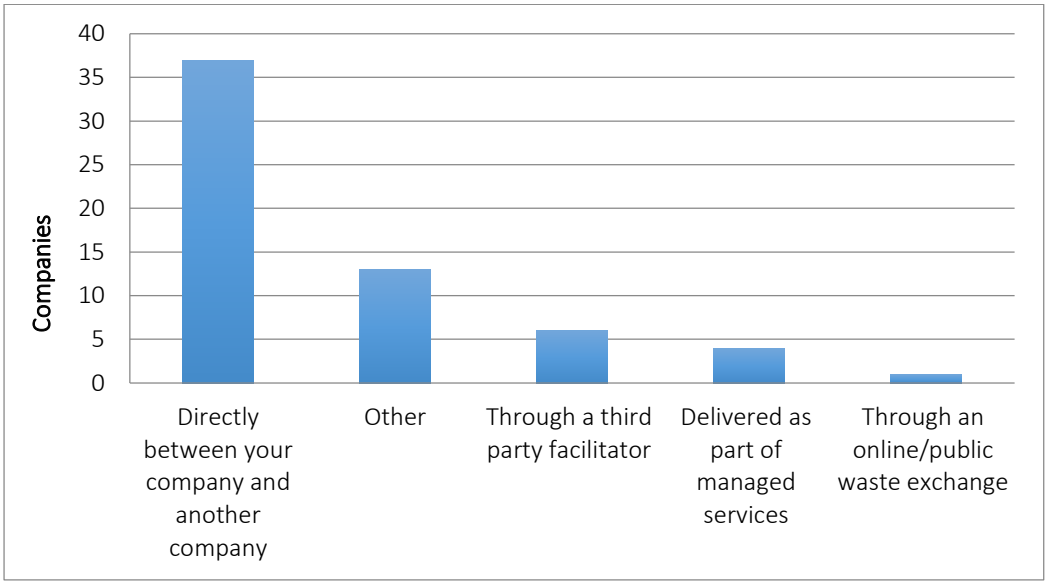
	Turkish	Spanish	German	English	**Total**
Process barriers	10	7	1	6	**24**
Regulatory barriers	12			8	**20**
Financial barriers	7	5		8	**20**
Transport barriers	10	2	2	5	**19**
Lack of information regarding alternative feedstock/inputs	2	6		8	**16**
Lack of time to implement solutions	1	6	1	6	**14**
Long timeframe for implementation of solutions	4	2		6	**12**
Other	6	2	1	2	**11**
Coordination barriers	3	2		3	**8**
Concerns about confidentiality	2	1		3	**6**
Gaining approval from relevant authorities	3			3	**6**
Contractual barriers	1	2		2	**5**
Logistical barriers				1	**1**

[5] Ehrenfeld, J and Gertler, N (1997) "Industrial Ecology in Practice: The Evolution of Interdependence at Kalundborg", Journal of Industrial Ecology, 1(1): 67-79

Actions taken

Of the companies undertaking actions to identify alternative uses for their waste, or alternative inputs, the predominant action implemented was as an arrangement made directly between the respondent's company and another company. Other popular options for implementation were through a third party facilitator and as part of managed services, as illustrated in Figure 4.

Figure 4 Survey results: implementation of industrial symbiosis



4.2. Practitioner responses: role of facilitation in overcoming barriers

To date, facilitation has been as fundamental to successfully achieving industrial symbiosis: supporting companies through opportunity identification and process management through to completion. These dual functions of facilitation are currently performed in the various versions of NISP® in operation around the world. This model of industrial symbiosis is not premised on the use of ICT, however ICT plays an important role in supporting practitioners' activities.

Regulatory and policy barriers:

As professional facilitators of industrial symbiosis, International Synergies staff have worked on numerous standards and specifications addressed by the Waste Framework Directive across Europe, and beyond. International Synergies contributed to the development of the UK waste standards or Quality Protocols[6], enabling recovered products to be used without the need for waste regulation controls. To date International Synergies has worked to remove the regulatory burden of waste reuse in Quality Protocols for biodiesel, plastics, tyre-derived rubber and waste oils. Similarly through dialogue with the UK Environment Agency, exemptions have been granted or reclassifications have been made e.g. from hazardous to non-hazardous in the case of some foundry sands.

The companies surveyed ranked regulatory barriers as the second most important barrier to industrial symbiosis; yet 'gaining approval from relevant authorities' ranked rather low; it is possible that this is

[6] UK Quality Protocols set out the steps required for waste to become a non-waste product or material that can be legally either reused by business or industry, or supplied into other markets.

because most companies do not consider the possibility of engaging in dialogue with the regulators for clarifications or exemptions, whereas professional facilitators know that this is often a productive avenue to advance a synergy. Practitioners interviewed confirmed that they are often called upon to provide knowledge of regulations and to be a 'go-between' with the regulator.

Information barriers:

Practitioners observe that companies familiar with industrial symbiosis were more likely to be aware of alternative resources, and to initiate the search for projects. However, even those familiar with the concept of reuse may be unable to find alternative materials. In practice, facilitators have (through their own knowledge or the knowledge of a network), or have access to, the relevant technical and specialist knowledge to identify and advance synergies between companies: viable applications and uses for materials; third party/additional processing required; waste regulations; transport pricing and options; as well as expertise and/or skills to develop new solutions.

Organisational and governance barriers:

The NISP® model of facilitated/ICT industrial symbiosis includes business opportunity workshops at which resources and potential matches are identified; in most countries, the companies attending receive a complete report after each workshop that details the resources identified and the companies potentially interested in them as either a supply or a demand. It is rare in every country that the company then advances the opportunities on its own (exceptions are 'quick wins' that are completed outside of the facilitated programme, although the opportunity was identified within it); this is generally interpreted as due to a lack of confidence in one's own expertise, a lack of time to pursue the opportunity (which won't yet be well defined vis a vis return on investment), and lack of motivation to pursue an opportunity that is outside the BAU experience. When practitioners were asked whether businesses would search for their own alternative resources if they had the mechanism to do so, the general response was that they had the ability but not the will, or the time. It was also observed to be dependent on the company culture (for example, willingness to challenge & change standard operating procedures).

Practitioners also tended to draw a distinction in behaviour between large multi-national corporations (MNCs) and small medium enterprises (SMEs), whereby MNCs generally have enough staff time and budget to invest in exploring such concepts, however SMEs generally do not.

Central to advancing a new supply chain opportunity is the potentially lengthy process of testing a new material or process to ensure it meets specifications, then negotiating and agreeing a new contract. Facilitators are often called on to coordinate parties throughout this process. As many opportunities require more than two parties, and/or involve innovative approaches new to the company, the facilitator often helps research the opportunity (technologies, materials etc.) and go on to identify partners and coordinate efforts.

A practitioner in South Africa also highlighted the need to challenge businesses' preconceptions, especially their perception of secondary materials being of lower quality/standard compared with primary materials. A steady flow of information and case studies is often required to overcome some of these preconceptions.

Commercial barriers:

Helping to establish commercial viability was not mentioned by the practitioners as a key role; this is consistent with International Synergies' experience, where the companies generally develop their own cost-benefit analysis and return on investment for an industrial symbiosis opportunity. Practitioners have been called on to support the negotiation with benchmarking and competitor analysis; however this response further substantiates the observation that, once an opportunity is defined, industrial

symbiosis is just BAU.[7] Facilitators have also been able to assist companies by signposting to available grants whether at a local, regional or national level, through their knowledge and/or network of contacts.

5. Discussion and Conclusion

Industrial symbiosis is a priority for Europe. The business-friendly approach to low-carbon growth and resource efficiency has been explicitly recognised by the European Commission. DG Enterprise & Industry has identified that the 'information market failure' in relation to resource efficiency can be addressed by setting up mechanisms to improve information flow between businesses[8]. DG Enterprise & Industry has further identified enhanced industrial symbiosis as a recommended policy instrument to overcome this information market failure[9]. DG Regions has incorporated industrial symbiosis into *Connecting Smart and Sustainable Growth* (2012). The effectiveness of industrial symbiosis in delivering Europe's climate change objectives has been evidenced by research undertaken for DG Environment[1] that identified International Synergies Limited's facilitated industrial symbiosis programme (NISP®) as one of the most effective resource efficiency policies in the world.

Industrial symbiosis addresses this information market failure by connecting traditionally separate industries through facilitated synergies, thus enabling them to divert underutilised resources (including energy, materials, water and capacity) into productive and value-added uses elsewhere in the economy while reducing associated carbon emissions. This holistic approach has demonstrated in practice positive impacts on materials, water and energy use, innovation, knowledge transfer and best practice sharing, capacity utilisation, and job creation.

The facilitated with ICT support model of industrial symbiosis has proven much more effective at engaging companies, capturing resources and advancing synergies than the ICT alone model, but is more expensive to deliver and thus more difficult to scale up. The aim of SHAREBOX is to develop an ICT resource management database that overcomes the shortcomings of existing ICT alone systems, and the barriers identified in this report. Incorporating (many of) the advantages of facilitation into the ICT will be key to its success, as demonstrated by the success of active facilitation to deliver industrial symbiosis.

This study of non-technical barriers to industrial symbiosis has identified priority areas where input from practitioners is most valued by companies. The challenges and barriers identified by the survey respondents inform the prioritisation of issues to be addressed in the next generation ICT-alone resource management database, focusing on informational and organisational barriers. The practitioners' perspective on the benefits of facilitation included: supporting businesses to maintain momentum in advancing opportunities; accessing expertise to help with practical questions; additional resource to pursue opportunities and provide research support to identify opportunities and overcome barriers; experience assessing the replicability of (potential) solutions.

Of the non-technical barriers to industrial symbiosis explored through survey and interviews, c**ommercial viability** is not an area for substantial practitioner intervention: companies do not need (much) help with building the commercial case. Both companies and practitioners identify **regulation and policy** as potential barriers, usually addressed through facilitation. The lack of **information availability** is clearly identified as a barrier by companies, and a large part of the practitioners' role.

[7] Ehrenfeld & Gertler (1997) ibid; Lombardi & Laybourn (2012) ibid.; Branson (2011) ibid.

[8] Study on the Competitiveness of the European Companies and Resource Efficiency, *ECORYS* for DG Enterprise & Industry, 2011

[9] Sustainable Industry: Going for Growth, DG Enterprise & Industry, 2011

Finally, **organisational and governance** issues are acknowledged as a barrier by both practitioners and companies (process barriers, lack of time, coordination). The ranking of benefits of industrial symbiosis also indicates that the concept is seen mainly as a way of dealing with waste, rather than sourcing alternative feedstock. This is consistent with facilitated industrial symbiosis experience, where most companies start off identifying more 'wastes' to dispose of than opportunities to use them.